

Global impact of the COVID-19 pandemic on subarachnoid haemorrhage hospitalisations, aneurysm treatment and in-hospital mortality: 1-year follow-up

(SVIN COVID-19 Global SAH Registry) Nguyen, Thanh N.; Roje Bedekovic, Marina; Budincevic, Hrvoje

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Original research

Global impact of the COVID-19 pandemic on subarachnoid haemorrhage hospitalisations, aneurysm treatment and in-hospital mortality: 1-year follow-up

SVIN COVID-19 Global SAH Registry

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Correspondence to

Thanh N. Nguyen, Boston University School of Medicine, Boston, MA 02118, USA; thanh.nguyen@bmc.org and Raul G. Nogueira, Cerebrovascular Center, University of Pittsburgh Medical Center, 200 Lothrop Street, Pittsburgh, PA, USA; Raul.G.Nogueira@icloud.com

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ABSTRACT

Background Prior studies indicated a decrease in the incidences of aneurysmal subarachnoid haemorrhage (aSAH) during the early stages of the COVID-19 pandemic. We evaluated differences in the incidence, severity of aSAH presentation, and ruptured aneurysm treatment modality during the first year of the COVID-19 pandemic compared with the preceding year.

Methods We conducted a cross-sectional study including 49 countries and 187 centres. We recorded volumes for COVID-19 hospitalisations, aSAH hospitalisations, Hunt-Hess grade, coiling, clipping and aSAH in-hospital mortality. Diagnoses were identified by International Classification of Diseases, 10th Revision, codes or stroke databases from January 2019 to May 2021.

Results Over the study period, there were 16 247 aSAH admissions, 344 491 COVID-19 admissions, 8300 ruptured aneurysm coiling and 4240 ruptured aneurysm clipping procedures. Declines were observed in aSAH admissions (−6.4% (95% CI −7.0% to −5.8%), $p=0.0001$) during the first year of the pandemic compared with the prior year, most pronounced in high-volume SAH and high-volume COVID-19 hospitals. There was a trend towards a decline in mild and moderate presentations of subarachnoid haemorrhage (SAH) (mild: −5% (95% CI −5.9% to −4.3%), $p=0.06$; moderate: −8.3% (95% CI −10.2% to −6.7%), $p=0.06$) but no difference in higher SAH severity. The ruptured aneurysm clipping rate remained unchanged (30.7% vs 31.2%, $p=0.58$), whereas ruptured aneurysm coiling increased (53.97% vs 56.5%, $p=0.009$). There was no difference in aSAH in-hospital mortality rate (19.1% vs 20.1%, $p=0.12$).

Conclusion During the first year of the pandemic, there was a decrease in aSAH admissions volume, driven by a decrease in mild to moderate presentation of aSAH. There was an increase in the ruptured aneurysm coiling rate but neither change in the ruptured aneurysm clipping rate nor change in aSAH in-hospital mortality.

Trial registration number NCT04934020.

INTRODUCTION

More than 2 years since the identification of the first case of COVID-19 in December 2019, the global COVID-19 pandemic has resulted in more than 400 million cases and close to 6 million deaths worldwide. As the COVID-19 pandemic has

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ A decline in non-traumatic subarachnoid haemorrhage (SAH), aneurysmal subarachnoid haemorrhage (aSAH) hospitalisations and ruptured aneurysm coiling has been reported during the first wave of the pandemic. A relative increase in ruptured aneurysm coiling was noted in low-coiling volume hospitals of 41.1% despite a decrease in SAH admissions in this tertile.

WHAT THIS STUDY ADDS

⇒ At the 1-year follow-up, we confirm a continued decline in aSAH admissions (−6.4% (95% CI −7.0% to −5.8%)) compared with the prior year, mostly driven by a decline in the mild and moderate presentation of aSAH, but no difference noted in patients with higher severity of aSAH. Another new finding is an increase in the ruptured aneurysm coiling rate but neither change in ruptured aneurysm clipping rate nor change in aSAH in-hospital mortality.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ aSAH findings at 1 year are concordant with a decrease in other emergencies such as ischaemic stroke. A stable aSAH mortality rate may attest to the resilience of hospitals in the care of patients with aSAH during the pandemic.

continued throughout the globe, there has been increasing recognition of the systemic effects of infection. In addition to respiratory symptoms, COVID-19 infection disrupts normal coagulation. Aberrations in coagulation may serve as a source for abnormal clotting events such as venous thromboembolism, stroke and abnormal bleeding.

During the first wave of the COVID-19 pandemic, marked declines in patients presenting with acute cerebrovascular conditions were observed,^{1–8} including patients with non-traumatic subarachnoid haemorrhage (SAH).^{1–9 10} Our initial report demonstrated declines in non-traumatic SAH (−22.5%) and aneurysmal subarachnoid haemorrhage (aSAH) (−24.9%) hospitalisations over the first 3 months of the pandemic as compared with



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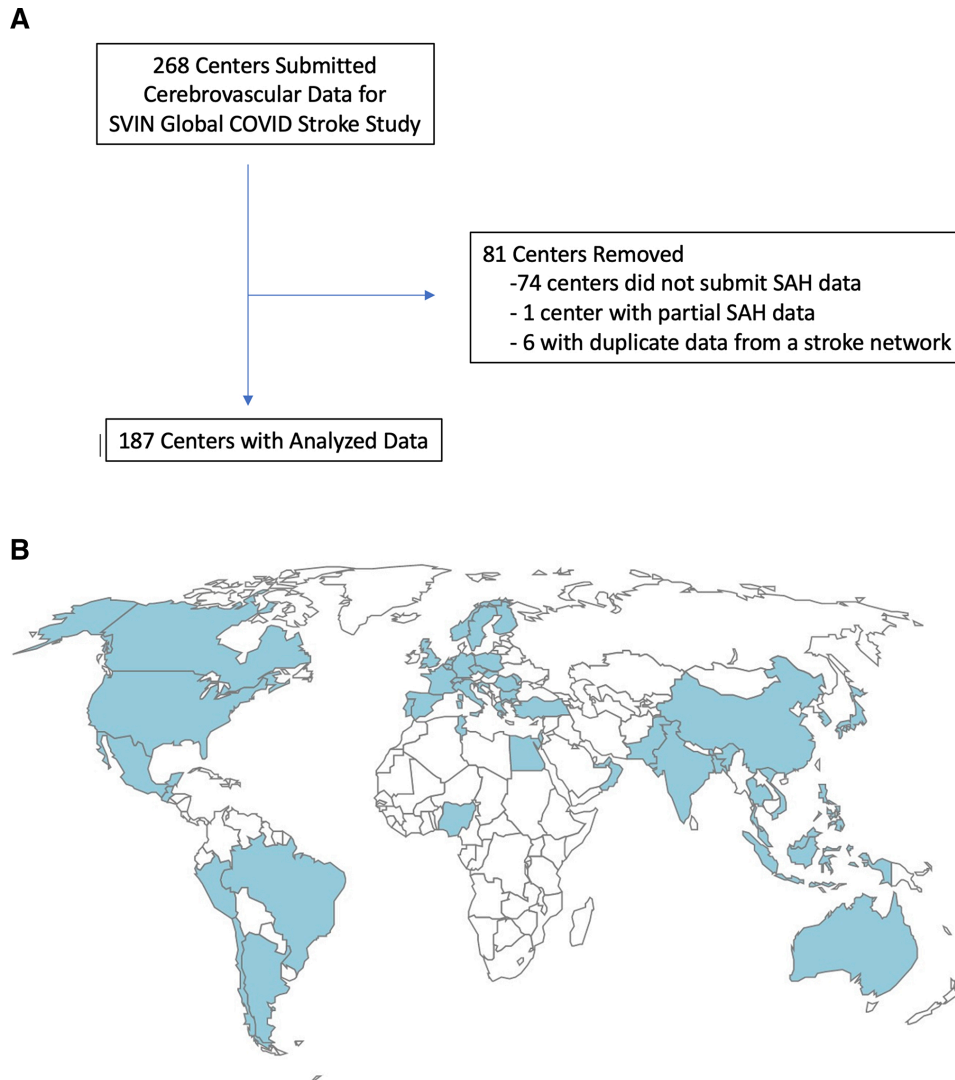


Figure 1 (A) Study flowchart. (B) World map of study countries. SAH, subarachnoid haemorrhage; SVIN, Society of Vascular and Interventional Neurology.

the corresponding 3 months of the prior year. A single-centre study from Lille reported greater disease severity and delayed presentation among patients with aSAH.¹¹

Ruptured aneurysm coiling procedures also declined overall, but an increase in coiling procedures at low-volume centres suggested a potential shift in treatment.¹ Higher mortality, longer intensive care unit (ICU) stays and longer hospitalisations¹² have been observed in patients with both SAH and COVID-19 compared with those with SAH alone.¹³ The long-term 1-year repercussions of the COVID-19 pandemic on aSAH admission volumes have not been studied, and it is unknown whether the declines during the first wave of the pandemic were related to a change in the severity of disease presentation.

Objectives and prespecified hypothesis

The primary objectives of this study were to evaluate changes in the volume of non-traumatic SAH, aSAH hospitalisations and aSAH in-hospital mortality during the first year of the COVID-19 pandemic (1 January 2020 to 28 February 2021) compared with the preceding year (1 January 2019 to 29 February 2020), adjusted by the beginning month of the pandemic by country. The secondary objectives were to evaluate the severity of aneurysmal aSAH admission presentation,

the modality treatment of aSAH and the associations between COVID-19 admission volumes and aSAH volumes over the same period.

Our primary hypothesis was that, similar to the first wave, there would be a decrease in SAH and aSAH hospitalisations between the first year of the COVID-19 pandemic and the preceding year. Our secondary hypothesis was that there could be a shift toward increased use of ruptured aneurysm coiling as we had observed in the first wave of the pandemic.

METHODS

Study design

We conducted a cross-sectional retrospective study evaluating consecutive patients hospitalised with a diagnosis of subarachnoid haemorrhage between 1 January 2019 and 31 May 2021. Primary data collection was conducted between 1 May 2021 and 15 September 2021. A physician or research coordinator verified cases at each site, and follow-up queries to sites by the lead author were completed by 15 January 2022.

This study followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guideline.

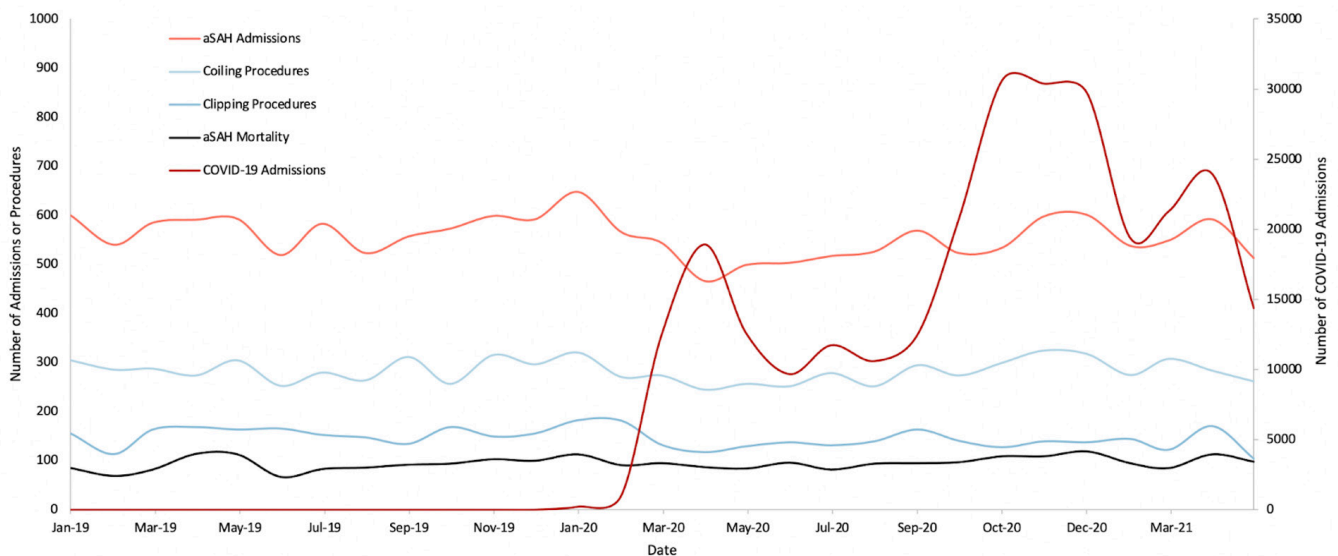


Figure 2 aSAH, coiling, clipping, mortality, COVID-19 admissions. aSAH, aneurysmal subarachnoid haemorrhage.

Setting and participants

Data were collected from collaborators of the Society of Vascular and Interventional Neurology, the Middle East North Africa Stroke and Interventional Neurotherapies Organisation, the Japanese Interventional Neurology Society, the European Stroke Organisation, the Latin America Stroke Group and academic partners.

Of 450 centres invited to participate in this global study of the impact of COVID-19 on cerebrovascular disease (including stroke, cerebral venous thrombosis and subarachnoid haemorrhage), data were received from 268 centres. Of these 268 centres, 74 centres did not submit SAH data and 1 had partial SAH data. There were six centres removed from the Czech Republic to ensure no data duplication because these centres referred patients with SAH to other centres that submitted SAH data in this cohort. This yielded 187 centres for this study cohort (figure 1A,B). The study size was based on the number of submitted cases with complete data for each variable.

The start date of the COVID-19 pandemic in each country was determined as the date of the first reported case. We defined the second wave of the COVID-19 pandemic using two definitions. Our primary definition was a minimum doubling of case volume following a $\geq 50\%$ decline in case volume from the previous wave's peak. The start date for this occurrence was chosen as the case volume minimum closest to the second wave. Our secondary definition was the primary definition plus a minimum of 2 months between the peak of the first wave and the start of the second wave.^{14 15} Centres were divided by low-volume, intermediate-volume and high-volume strata by mean monthly volume tertiles for COVID-19 hospitalisation submitted data (<26.33 vs >26.33 to 126.53 vs >126.53).

Study variables and outcome measures

We collected data on monthly aSAH, non-traumatic SAH hospitalisation volume, aSAH in-hospital mortality, ruptured aneurysm treatment modality with coiling or clipping, and COVID-19 hospitalisation volume. Non-traumatic SAH hospitalisation included patients with aSAH, perimesencephalic SAH or spontaneous convexal SAH. aSAH included patients who presented with ruptured aneurysm. Centres were divided by low-volume, intermediate-volume and high-volume centres by mean monthly

volume tertiles for aSAH hospitalisation submitted data prior to the pandemic (<1.54 vs >1.54 to 3.33 vs >3.33).

For patients with aSAH, we categorised aSAH severity according to the Hunt and Hess (HH) scale: grade 1 or 2 as mild severity, grade 3 as moderate severity, and grade 4 or 5 as severe. Mortality data were obtained for aSAH admissions and were defined as a patient with aSAH who died in-hospital or was being transitioned to hospice care.

SAH data were obtained by a prospectively maintained aneurysm database or by International Classification of Diseases, 10th Revision (ICD-10) codes: I60 (non-traumatic SAH), I60.0 (non-traumatic SAH from carotid siphon and bifurcation), I60.1 (non-traumatic SAH from middle cerebral artery), I60.2 (non-traumatic SAH from anterior communicating artery), I60.3 (non-traumatic SAH from posterior communicating artery), I60.4 (non-traumatic SAH from basilar artery), I60.5 (non-traumatic SAH from vertebral artery), I60.6 (non-traumatic SAH from other intracranial arteries), I60.7 (non-traumatic SAH from intracranial artery, unspecified) I60.8 (other non-traumatic SAH) and I60.9 (non-traumatic SAH unspecified).

COVID-19 hospitalisation was defined as a patient admitted using ICD-10 code U07.1 (COVID-19, virus identified), including those without a neurological diagnosis.

Standard protocol approvals, registrations and patient consents

This was an investigator-initiated study. There were no protected health information data collected in this study.

Bias

Data collection was completed more than 3 months after the final date of patient inclusion to ensure complete data capture including mortality events. Data verification was conducted by the lead author (TNN) on receipt of site data and centres with incomplete data were excluded from the subgroup analysis in which the data were missing. Centres contributing data within a stroke network were instructed to include transferred patients at the site of initial evaluation only. COVID-19 waves were evaluated based on publicly available data and the actual dates may not have been captured, especially early

Table 1 (A) aSAH admissions overall and monthly volumes before and during the COVID-19 pandemic. (B) SAH admissions by severity: overall and monthly volumes before and during the COVID-19 pandemic

(A)									
		Overall volume				Monthly volume*			
		Before COVID-19†	During COVID-19‡	Change % (95% CI)	P value	N	Before COVID-19 Adjusted mean (SE)	During COVID-19	P value
	N								
Overall	165	6912	6471	-6.4 (-7.0 to -5.8)	0.0001	172	3.84 (0.75)	3.62 (0.74)	0.03
Hospital aSAH volume§									
Low	56	422	471	11.6 (8.9 to 15.0)	0.101	57	0.56 (0.09)	0.64 (0.11)	0.142
Int.	53	1460	1472	0.82 (0.47 to 1.4)	0.825	56	2.28 (0.12)	2.28 (0.15)	0.977
High	56	5030	4528	-10.0 (-10.8 to -9.2)	<0.0001	59	8.14 (1.41)	7.42 (1.39)	0.008
Hospital aSAH volume stratified by hospital COVID-19 volume¶									
Low	49	1788	1833	2.5 (1.9 to 3.4)	0.455	52	2.94 (1.02)	3.0 (1.03)	0.657
Int.	46	1456	1368	-6.0 (-7.4 to -4.9)	0.098	46	2.19 (0.73)	2.03 (0.68)	0.19
High	47	2275	2074	-8.8 (-10.1 to -7.7)	0.002	49	3.77 (1.18)	3.40 (1.15)	0.137
(B)									
		Overall volume				Monthly volume*			
		Before COVID-19†	During COVID-19‡	Change % (95% CI)	P value	N	Before COVID-19 Adjusted mean (SE)	During COVID-19	P value
	N								
Mild	125	2698	2562	-5.0 (-5.9 to -4.3)	0.061	125	1.92 (0.37)	1.83 (0.36)	0.205
Mod.	125	981	900	-8.3 (-10.2 to -6.7)	0.062	125	0.60 (0.09)	0.55 (0.09)	0.204
Severe	125	1508	1490	-1.2 (-1.9 to -0.75)	0.742	125	0.87 (0.16)	0.86 (0.17)	0.78

Table 1b: Mild, moderate and severe cases were defined as Hunt-Hess grades 1–2, 3 and 4–5, respectively. 125 hospitals submitted complete data 12-month prepandemic and pandemic data on grades.

*The monthly volume analysis is adjusted for the date of peak COVID-19 volume for each country, the start date of the second wave and the continent.

†Number of admissions during 12 months before COVID-19 pandemic.

‡Number of admissions during 12 months of COVID-19 pandemic.

§P value: low versus int. ≤ 0.0001 ; low versus high=N/A; int. versus high=N/A.

¶P value: low versus int.=N/A, low versus high=N/A, int. versus high=0.002.

aSAH, aneurysmal subarachnoid haemorrhage; int., intermediate; mod., moderate; N/A, not applicable; n, number of hospitals; SAH, subarachnoid haemorrhage.

in the pandemic and in nations where testing was not widely available. In nations with extremes of COVID-19 incidence, pandemic waves were obscured and not well captured by our definitions for the second wave of the pandemic.

Statistical analysis

We compared percentage change in the absolute number of aSAH admissions, non-traumatic SAH admissions, the severity of aSAH, endovascular coiling, aneurysm clipping, and aSAH mortality before and during the COVID-19 pandemic.

The 95% CIs for percentage change were calculated using the Wilson procedure without correction for continuity. The differences in admissions across the two periods were assessed for significance using the Poisson means test. The analysis was repeated within categories of hospital aSAH volume (low, intermediate or high) and hospital COVID-19 volume (low, intermediate or high). The relative percentage decrease in volume between different categories (eg, low vs intermediate hospital volume) was tested using the z-test of proportion.

Table 2 aSAH admissions overall and monthly volumes per continent before and during the COVID-19 pandemic

		Overall volume				Monthly volume*				
		N	n1	n2	Change % (95% CI)	P value	N	Immediately before Adjusted mean (SE)	During COVID-19	P value
Overall	165	6912	6471	-6.4 (-7.0 to -5.8)	0.0001	172	3.84 (0.75)	3.62 (0.74)	0.030	
Europe	59	2056	1944	-5.4 (-6.5 to -4.6)	0.077	62	2.90 (0.33)	2.74 (0.36)	0.290	
North America	48	1856	1849	-0.38 (-0.78 to -0.18)	0.908	48	3.22 (0.51)	3.21 (0.46)	0.908	
Asia	45	2340	2178	-6.9 (-8.0 to -6.0)	0.016	48	4.28 (0.81)	4.03 (0.72)	0.270	
South America	8	435	291	-33.1 (-37.7 to -28.8)	<0.0001	9	4.84 (2.09)	3.28 (1.36)	0.121	
Africa	4	146	146	0.0 (0 to 2.6)	1.0	4	3.04 (0.23)	3.04 (0.23)	1.0	
Oceania	1	79	63	-20.3 (-30.4 to -12.9)	0.180	1	-	-	-	

*The monthly volume analysis for each continent is adjusted for the date of peak COVID-19 volume for each country and the start date of the second wave. The overall monthly volume analysis is also adjusted for the continent.

aSAH, aneurysmal subarachnoid haemorrhage; n1, number of admissions during 12 months before the COVID-19 pandemic; n2, number of admissions during 12 months of COVID-19 pandemic; n, number of hospitals; SAH, subarachnoid haemorrhage.

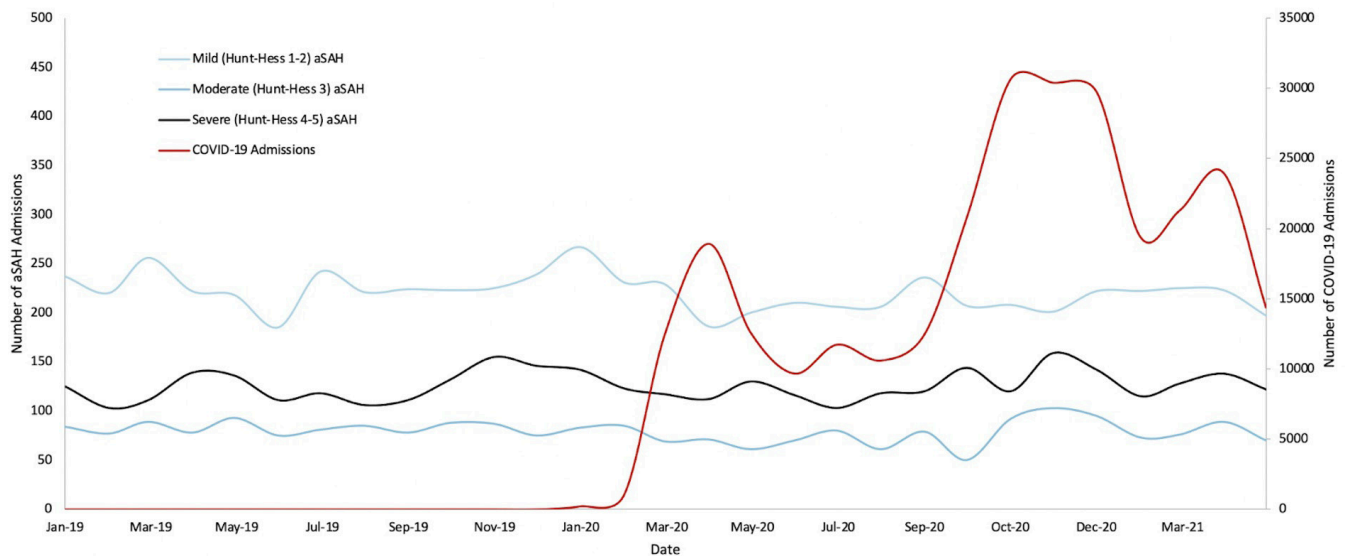


Figure 3 Hunt-Hess grade presentation and COVID-19 admissions.

In addition to absolute volume analysis, we also compared average monthly volumes (admissions/month) for the periods mentioned previously. The data were analysed in a mixed design using a repeated-measures analysis of variance (PROC MIXED analysis in SAS) accounting for the paired data structure and potential covariates. The unstructured matrix was the best fit and was used for the analyses. The monthly hospital volume analysis was adjusted for the date of peak COVID-19 volume for each country, the start date of the second wave and the continent. Estimated marginal means were calculated using the LSMEANS statement in PROC MIXED. The monthly volume analysis was stratified by aSAH and COVID-19 volume like the overall volume analysis.

Finally, we compared aSAH in-hospital mortality rate (aSAH mortality/aSAH admissions) before and during the COVID-19 pandemic using the χ^2 test. The difference in in-hospital mortality in patients with aSAH with or without concomitant COVID-19 was also tested using the χ^2 test. All data were analysed using SAS V.9.4, and the significance level was set at a p value of <0.05 . No adjustments were made for multiple hypothesis testing.

Data availability

Data are available on reasonable request from the corresponding author.

RESULTS

Over the study period from January 1, 2019, to May 31, 2021, there were 20 680 non-traumatic SAH admissions and 344 491 COVID-19 admissions among participating centres. Of these, there were 16 247 aSAH admissions. There were 8300 endovascular coiling procedures and 4240 aneurysmal clipping procedures over the study period (figure 2).

1-year aSAH admissions

There were 6912 patients with aSAH admissions 1 year prior to the pandemic compared with 6471 during the pandemic, representing a 6.4% decrease (95% CI -7.0% to -5.8% , $p=0.0001$; table 1A) with continental variation (table 2). Monthly aSAH also declined from a mean of 3.8 (SE 0.75) to 3.6 (SE 0.74) patients per month, per centre. The decline in aSAH was most

pronounced in high-volume aSAH hospitals (-10% (95% CI -10.8% to -9.2%), $p<0.0001$) and high-volume COVID-19 hospitals (-8.8% (95% CI -10.1% to -7.7%), $p=0.002$). Non-traumatic SAH admissions also exhibited decline over the same time period (overall: -4.1% (95% CI -4.6% to -3.7%), $p=0.006$; monthly mean 5.3 (SE 0.89) to 5.0 (SE 0.89), $p=0.003$; online supplemental table S1). Similar to aSAH, the declines were most marked in high non-traumatic SAH volume and high-volume COVID-19 centres (online supplemental table S1).

Severity of aSAH presentation

There were 125 hospitals that submitted complete data on aSAH severity on presentation using the HH grading scale. There was a trend towards a decline in mild and moderate presentations of aSAH (mild: -5% (95% CI -5.9% to -4.3%), $p=0.06$; moderate: -8.3% (95% CI -10.2% to -6.7%), $p=0.06$) but no difference noted in patients with higher severity of aSAH (table 1B and figure 3).

Ruptured aneurysm coiling

Overall, there were no changes in endovascular coiling of ruptured aneurysms before and during the pandemic. In subgroup analysis, hospitals with low aSAH volume prepandemic exhibited an increase in coiling procedures for ruptured aneurysms (26.2% (95% CI 20.4% to 33.1%), $p=0.02$, $n=42$ centres; table 3A). No difference in coiling volume was seen across hospitals with low-volume, intermediate-volume or high-volume COVID-19 hospitalisation.

Ruptured aneurysm clipping

Overall, there was a decline in aneurysm clipping procedures for ruptured aneurysms in the 1 year before and during the pandemic (-9.3% (95% CI -10.7% to -8.1%), $p=0.004$, $n=140$ centres; table 3B). The decline was most prominent in centres with high aSAH volume prior to the pandemic (-13.6% (95% CI -15.6% to -12.0%), $p=0.0002$) and with high COVID-19 hospitalisation burden (-22.7% (95% CI -26.5% to -19.3%), $p=0.0001$)

Table 3 (A) Endovascular coiling admissions overall, monthly volumes before and during the COVID-19 pandemic, and (B) surgical clipping admissions overall and monthly volumes before and during the COVID-19 pandemic

(A)									
	Overall volume					Monthly volume*			
	N	n1	n2	Change	P value	N	Before COVID-19	During COVID-19	P value
				% (95% CI)			Adjusted mean (SE)		
Overall	152	3464	3374	-2.6 (-3.2 to -2.1)	0.276	166	2.06 (0.44)	2.02 (0.43)	0.518
Hospital endovascular coiling volume stratified by prepandemic aSAH volume††									
Low	42	183	231	26.2 (20.4 to 33.1)	0.019	47	0.35 (0.09)	0.45 (0.10)	0.058
Int.	54	842	813	-3.4 (-4.9 to -2.4)	0.476	56	1.28 (0.15)	1.26 (0.15)	0.783
High	50	2240	2135	-4.7 (-5.7 to -3.9)	0.112	55	4.13 (0.82)	3.97 (0.81)	0.269
Hospital endovascular coiling volume stratified by hospital COVID-19 volume‡‡									
Low	45	851	870	2.2 (1.4 to 3.5)	0.647	49	1.44 (0.46)	1.48 (0.45)	0.729
Int.	42	798	828	3.8 (2.7 to 5.3)	0.457	45	1.35 (0.45)	1.41 (0.44)	0.495
High	44	1047	990	-5.4 (-7.0 to -4.2)	0.207	48	2.12 (0.78)	2.0 (0.78)	0.273
(B)									
	Overall volume					Monthly volume*			
	N	n1	n2	Change	P value	N	Before COVID-19	During COVID-19	P value
				% (95% CI)			Adjusted mean (SE)		
Overall	140	1848	1676	-9.3 (-10.7 to -8.1)	0.004	151	1.29 (0.42)	1.18 (0.43)	0.067
Hospital clipping volume stratified by prepandemic aSAH volume§§									
Low	40	91	101	11.0 (6.1 to 19.1)	0.471	45	0.13 (0.05)	0.14 (0.06)	0.616
Int.	50	350	368	5.1 (3.3 to 8.0)	0.502	51	0.61 (0.11)	0.63 (0.12)	0.826
High	47	1392	1202	-13.6 (-15.6 to -12.0)	0.0002	51	2.65 (0.90)	2.32 (0.93)	0.034
Hospital clipping volume stratified by hospital COVID-19 volume¶¶									
Low	45	650	672	3.4 (2.2 to 5.1)	0.545	47	0.40 (0.68)	0.44 (0.72)	0.655
Int.	37	411	387	-5.8 (-8.5 to -4.0)	0.396	41	0.68 (0.46)	0.63 (0.48)	0.308
High	42	519	401	-22.7 (-26.5 to -19.3)	0.0001	44	1.16 (0.29)	0.89 (0.23)	0.102

*The monthly volume analysis is adjusted for the date of peak COVID-19 volume for each country, the start date of the second wave, and the continent.
†P value: low versus int.=N/A, low versus high=N/A, int. versus high=0.115.
‡P value: low versus int.=0.056, low versus high=N/A, int. versus high=N/A.
§P value: low versus int.=0.040, low versus high=N/A, int. versus high=N/A.
¶P value: low versus int.=N/A, low versus high=N/A, int. versus high≤0.0001.
aSAH, aneurysmal subarachnoid haemorrhage; int., intermediate; n1, number of admissions during 12 months before COVID-19 pandemic; n2, number of admissions during 12 months of COVID-19 pandemic; N/A, not applicable; n, number of hospitals; SAH, subarachnoid haemorrhage.

Rate of ruptured aneurysm coiling or clipping

There were 132 centres that reported complete data on aSAH admissions, coiling and clipping in the 1 year before and during the pandemic. In this cohort, while the number of aneurysm clipping declined numerically, the rate of aneurysm clipping of the total aSAH admissions remained unchanged in the previous 1 year compared with during the pandemic (30.7% (1724/5616) vs 31.2% (1624/5205), $p=0.58$), whereas the rate of aneurysm coiling increased (53.97% (3031/5616) vs 56.5% (2940/5205), $p=0.009$).

SAH mortality

In patients with aSAH, there was no difference in the in-hospital or short-term mortality rate in the 1 year prepandemic compared with the first year of the pandemic (19.1% (1129/5918) vs 20.1% (1181/5654), $p=0.12$). In subgroup analysis, compared with the prepandemic year, there was an increase in aSAH mortality during the pandemic year in hospitals with higher tertile aSAH volume (17.3% (725/4191) vs 19.9% (771/3870), $p=0.003$) and high COVID-19 hospitalisation burden (21.9% (445/2035) vs 26.0% (495/1907), $p=0.003$) (table 4). Low-volume and

medium-volume aSAH hospitals demonstrated no change in mortality during or prepandemic (table 4).

COVID-19 and aSAH

There were 42 centres that submitted data on the concomitant presence of COVID-19 and aSAH, which was present in 2.3% (60/2651) of patients with aSAH and 0.07% (60/85 506) of COVID-19 admissions over the first year of the COVID-19 pandemic (table 5).

DISCUSSION

In this multinational, cross-sectional study, we observed a 6.4% decrease in aSAH admissions during the first year of the COVID-19 pandemic compared with the 1-year period prior to the pandemic. The decrease in aSAH admissions was most profound in the tertile of high-volume aSAH hospitals and high-volume COVID-19 hospitals, whereas a non-significant numerical increase in aSAH volume was seen in low-volume aSAH and low-volume COVID-19 hospitals, respectively. We therefore concede with the possibility that aSAH rates may not have changed, and that patients were shifted to being treated

Table 4 SAH in-hospital mortality rate 1 year previously compared with 1 year during the COVID-19 pandemic

	Overall volume			Mortality rate (%)	P value
	N	aSAH admissions	Mortality		
Overall					
Before COVID	144	5918	1129	19.08	0.12
During COVID		5654	1181	20.89	
Hospital aSAH volume: low					
Before COVID	46	325	94	28.92	0.936
During COVID		377	108	28.65	
Hospital aSAH volume: medium					
Before COVID	51	1402	310	22.11	0.678
During COVID		1407	302	21.46	
Hospital aSAH volume: high					
Before COVID	47	4191	725	17.30	0.003
During COVID		3870	771	19.90	
Centre COVID-19 volume: low					
Before COVID	47	1772	293	16.53	0.872
During COVID		1812	296	16.34	
Centre COVID-19 volume: intermediate					
Before COVID	42	1421	296	20.83	0.116
During COVID		1334	311	23.31	
Centre COVID-19 volume: high					
Before COVID	41	2035	445	21.87	0.003
During COVID		1907	495	25.96	

The periods before and during COVID-19 pandemic were defined as 12 months before and during the COVID-19 pandemic, respectively.
aSAH, aneurysmal subarachnoid haemorrhage; n, number of hospitals; SAH, subarachnoid haemorrhage.

at lower-volume COVID-19 hospitals if high-volume hospitals were overwhelmed with COVID-19 hospitalisations. A similar overall 4.1% decrease in non-traumatic SAH admission was also observed. There was a decline of 9.3% in the number of aneurysm clipping procedures for ruptured aneurysms performed but no difference in the number of endovascular coiling procedures. Moreover, the decline in ruptured aneurysm clipping was proportional to the decline in aSAH admission as the rate of aneurysm clipping was unchanged between the two epochs, whereas the rate of endovascular coiling per aSAH admission increased, suggesting a shift in treatment toward coiling.

Over the same time period, there was a trend toward a decline in presentation of both mild and moderate aSAHs, similar to reported decreases in the mild presentation of ischaemic stroke.¹⁶ There was no change in the in-hospital or short-term mortality rate between the year prior to and during the pandemic, attesting

to the emergency preparedness¹⁷ and resilience of hospitals in the care of patients with aSAH in the face of a global pandemic. However, the in-hospital or short-term mortality rate increased at high-COVID-19 volume and high-aSAH volume centres. To our knowledge, this is the first report to examine the effect of the COVID-19 pandemic on aSAH admissions, the severity of aSAH presentation, coiling and clipping volumes, in-hospital aSAH mortality over the 1 year of the COVID-19 pandemic compared with the previous year, across a large multinational cohort.

The mortality of patients with both COVID-19 and SAH has been reported to be more than four times greater compared with patients with SAH alone, likely attributed to concomitant comorbidities.¹³ Both prior to and during the pandemic, aSAH mortality was inversely related to centre aSAH volume tertile and directly related to centre COVID-19 volume tertile. During the pandemic, mortality rates were unchanged at low-volume and moderate-volume centres and were increased at high-volume centres for both aSAH (from 17.3% to 19.9%) and COVID-19 (from 21.9% to 26.0%). This increased mortality was observed in conjunction with a decrease in aSAH volume of 10.0% at high-aSAH volume centres and 8.8% at high-COVID-19 volume centres.

The decline in aSAH and non-traumatic SAH observed in this study mirrors the decreases in SAH volumes that have been previously reported^{19 10 18} during the first wave of the pandemic, whereas other centres have reported no change in aSAH volumes.¹⁹ The observed decrease of 6.4% in overall aSAH volume in our study was driven by a decreased presentation of mild and moderate aSAHs, at 5.0% and 8.3%, respectively. As expected, no change in the presentation of severe aSAH was observed. Patients with symptoms of mild or moderate aSAH may have been less likely to present to a hospital due to the perceived danger of medical facilities during the COVID-19 pandemic. Rebleeding and neurological deterioration rates within the first 24 hours of aSAH are high, estimated between 4% and 13.6% and 35%, respectively.^{20–22} This would likely result in patients with initially mild or moderate aSAH progressing to severe aSAH and presenting to a hospital. However, no increase in severe aSAH was observed, suggesting that lack of patient presentation does not sufficiently explain the decline seen in mild and moderate aSAHs. Late recurrence of treated aSAH is estimated to occur in 0.2%–0.3% annualised risk in treated patients, 22 times higher than matched controls.^{23 24} The rate of recurrent bleeding in untreated patients with aSAH may be higher.

Among 140 centres reporting surgical clipping, there was a decline of 9.3% in the number of aneurysm clipping procedures for ruptured aneurysms performed but no difference in the number of coiling procedures among 152 reporting centres.

Table 5 Rates of concomitant COVID-19 and aSAH admissions

	N	COVID-19 and aSAH	aSAH overall	COVID-19 overall	Fraction of aSAH % (95% CI)	Fraction of COVID-19 % (95% CI)
Overall	42	60	2651	85 506	2.3 (1.8 to 2.9)	0.07 (0.05 to 0.09)
Europe	11	19	459	18 764	4.1 (2.7 to 6.4)	0.10 (0.06 to 0.16)
North America	19	36	862	45 952	4.2 (3.0 to 5.7)	0.08 (0.06 to 0.11)
Asia	8	0	1117	5983	0 (0 to 0.3)	0.00 (0.00 to 0.08)
South America	3	1	113	7676	0.9 (0.2 to 4.8)	0.01 (0.00 to 0.07)
Africa	1	4	100	7101	4.0 (1.6 to 9.8)	0.06 (0.02 to 0.15)
Oceania	0	–	–	–	–	–

aSAH, aneurysmal subarachnoid haemorrhage; n, number of hospitals; SAH, subarachnoid haemorrhage.

Aneurysm clipping procedures declined most in centres with high aSAH volume prior to the pandemic and in centres with high COVID-19 hospitalisation burden. Meanwhile, at centres with low aSAH volume prepandemic, there was an increase of 26.2% in coiling procedures for ruptured aneurysms. These observed changes of relatively more endovascular coiling were also observed during the first wave of the pandemic⁴ and may be related to a shift to mitigate risks of perioperative infection to the patient and/or provider with less invasive endovascular techniques to secure the aneurysm. Another explanation of this shift to endovascular coiling may be related to conservation of hospital resources amidst a pandemic, whereby reduced hospital length of stay has been reported in patients with ruptured aneurysms who are coiled compared with those who are clipped.²⁵

Study limitations

While there were many centres in our study, the limitation is that data capture in our study may not have been complete without a comprehensive national database to account for regional differences in SAH care. We did not capture information on out-of-hospital death to account for potential rebleeding that may occur with a decline in mild to moderate SAH.

However, as several of our findings in this study, such as decrease in aSAH admissions or relative increase in coiling of ruptured aneurysms, were reproduced from the first wave of the pandemic, this may confirm the reproducibility and generalisability of our initial findings at the 1-year mark of the pandemic. Without granular data on patients presenting with aSAH, we could not identify confounding factors that might have explained higher in-hospital aSAH mortality during the pandemic in the hospitals with higher COVID-19 burden.

CONCLUSIONS

In conclusion, there was a decline in non-traumatic SAH and aSAH admissions during the first year of the COVID-19 pandemic. This decline was likely driven by an observed trend in the decline of patients presenting with mild to moderate aSAH. Overall, there was no significant difference in aSAH in-hospital mortality between the pandemic and prepandemic years, except in subgroup analysis of higher aSAH mortality in hospitals with the highest COVID-19 burden, attesting to resilience in the care of patients with aSAH amidst the pandemic. There was a decline in aneurysm clipping for ruptured aneurysms proportional to the decline in aSAH admissions during the first year of the pandemic and an increase in the coiling rate of ruptured aneurysms, suggesting a shift towards endovascular technique during the pandemic.

Co-authors SVIN Global COVID-19 SAH Registry: Thanh N Nguyen, MD (Neurology, Radiology, Boston Medical Center, Boston University School of Medicine, USA); Muhammad M Qureshi, MBBS (Radiology, Radiation Oncology, Boston Medical Center, Boston, USA); Piers Klein (Boston Medical Center, Boston, USA); Hiroshi Yamagami, MD, PhD (Department of Stroke Neurology, National Hospital Organization, Osaka National Hospital, Osaka, Japan); Robert Mikulik, MD, PhD (Department of Neurology, International Clinical Research Centre, St Anne's University Hospital and Faculty of Medicine, Masaryk University, Brno, Czech Republic); Nima Etminan, MD (Department of Neurosurgery, Mannheim University Hospital, Mannheim, Germany); Mohamad Abdalkader, MD (Radiology, Boston Medical Center, Boston, USA); Ossama Yassin Mansour, MD, PhD (Department of Neurology, Alexandria University Stroke and Neurointervention Unit, Alexandria, Egypt); Anna Czlonkowska, MD, PhD (2nd Department of Neurology, Institute of Psychiatry and Neurology, Warsaw, Poland); Hannah Lo (Boston University School of Medicine, Boston, USA); Anvitha Sathya (Boston University School of Medicine, Boston, USA); Jelle Demeestere, MD (Neurology Department, Leuven University Hospital, Leuven, Belgium); Georgios Tsvigoulis, MD, PhD MSc (Second Department of Neurology, 'Attikon' University Hospital, National and Kapodistrian University of Athens, Athens, Greece); Nobuyuki Sakai, MD (Department of Neurosurgery, Kobe

City Medical Center General Hospital); Petra Sedova, MD, PhD (Department of Neurology, International Clinical Research Centre, St. Anne's University Hospital and Faculty of Medicine, Masaryk University, Brno, Czech Republic); Department of Internal Medicine and Cardiology, University Hospital Brno, Brno, Czech Republic); Espen Saxhaug Kristoffersen, MD, PhD (Department of Neurology, Akershus University Hospital, University of Oslo, Oslo, Norway); Mahmoud Mohammaden, MD (Emory University School of Medicine); Argentina: Virginia Pujol Lereis, MD (Division de Neurologia Vascular, Departamento de Neurologia, Institute for Neurological Research, FLENI, Buenos Aires); Sergio Daniel Scollo, MD (Stroke Unit Ramos Mejia Hospital, Buenos Aires); Australia: Alice Ma, MBBS (Royal North Shore Hospital, Sydney); Bangladesh: Aminur Rahman, MD, FCPS (Department of Neurology, Sir Salimullah Medical College, Mitford, Dhaka, Bangladesh); Belgium: Thomas Bonnet, MD (Hopital Erasme, Brussels, Belgium); Jeroen Cortier, MD (Department of Neurosurgery, Universitair Ziekenhuis Brussel, Center for Neurosciences, Vrije Universiteit Brussel, Brussels, Belgium); Sylvie De Raedt, MD PhD (Department of Neurology, Universitair Ziekenhuis Brussel, Center for Neurosciences, Vrije Universiteit Brussel, Brussels, Belgium); Robin Lemmens, MD, PhD (Neurology Department, Leuven University Hospital, Leuven, Belgium); Noémie Ligot, MD (Hopital Erasme, Brussels, Belgium); Brazil: Raquel C T Hidalgo, MD (Hospital de Base de São José do Rio Preto, São Paulo); Daissy Liliana Mora Cuervo, MD (Moinhos de Vento Hospital, Brazil); Luciana de Oliveira Neves, MD (Hospital São Carlos, Brazil); Marco Túlio Salles Rezende, MD, MSc, PhD (Interventional Neuroradiology, Rede Mater Dei de Saúde, Belo Horizonte, Brazil); Igor Bessa Santiago, MD (Hospital São Carlos, Brazil); Bulgaria: Alexander Sirakov, MD (Department of Radiology, University Hospital St Ivan Rilski, Bulgaria); Stanimir Sirakov, MD (Department of Radiology, University Hospital St Ivan Rilski, Bulgaria); Canada: Elena Adela Cora, MD, PhD (Department of Diagnostic Radiology, Halifax Infirmary, Dalhousie University); Michael E Kelly, MD PhD (Royal University Hospital, Saskatoon, Saskatchewan, Canada); Pascale Lavoie, MD (CHU de Québec, Université Laval, Quebec, Canada); Lissa Peeling, MD (Royal University Hospital, Saskatoon, Saskatchewan, Canada); Aleksandra Pikula, MD (Toronto Western Hospital, University of Toronto, Toronto, Canada); Chile: Rodrigo Rivera, MD (Neuroradiology Department, Instituto de Neurocirugía Dr. Asenjo, Santiago, Chile); China: Hui-Sheng Chen, MD, PhD (Department of Neurology, General Hospital of Northern Theater Command, Shen Yang, China); Yimin Chen, MD (Department of Neurology, Foshan Sanshui District People's Hospital, China); Hongliang Fang, MD (Department of Quality Control, Foshan Sanshui District People's Hospital, China); Croatia: Marina Roje Bedekovic, MD (Sestre Milosrdnice University Hospital Center); Hrvoje Budincevic, MD, PhD (Sveti Duh University Hospital, Zagreb, Department of Neurology, Zagreb); Croatia: J J Strossmayer (University of Osijek, Faculty of Medicine, Department of Neurology and Neurosurgery, Osijek, Croatia); Czech Republic: Martin Čabal, MD (Neurology, Faculty Hospital Ostrava); Emanuela Hrabanovska, MD (Uherskohradištská Hospital, Czech Republic); Lubomír Jurák, MD PhD (Neurocenter, Regional Hospital Liberec, Czech Republic); Jana Kadlckova, MD (Neurology, Hospital Vyskov, Czech Republic); Igor Karpowicz, MD (Regional Hospital Karlovy Vary, Czech Republic); Lukáš Klečka, MD (Ostrava, Czech Republic); Martin Kovář, MD (Na Homolce Hospital, Czech Republic); Jiří Neumann, MD, FESO (Department of Neurology, Krajská zdravotní, a.s. - Hospital Chomutov, Chomutov, Czech Republic); Hana Paloušková, MD (Karvina Mining Hospital, Czech Republic); Martin Reiser, MD (Neurology, České Budejovice Hospital, České Budejovice); Petra Reková, MD (Department of Neurology and Centre of Clinical Neuroscience, First Faculty of Medicine, Charles University and General University Hospital in Prague, Prague, Czech Republic); Miroslav Škorňa, MD (Department of Neurology, Masaryk University Faculty of Medicine, University Hospital Brno, Brno, Czech Republic); Martin Šrámek, MD (Central Military Hospital in Prague, Czech Republic); Eva Vítková, MD (Department of Neurology, Comprehensive Stroke Center, Charles University Faculty of Medicine and University Hospital, Czech Republic); Lenka Žáková, MD (Nemocnice Třinec, Czech Republic); Egypt: Khalid Sobh, MD (El Hussein Alzhar University Hospital, Egypt); Finland: Kemal Alpay, MD (Department of Radiology, Turku University Hospital, Turku, Finland); Riitta Rautio, MD, PhD (Department of Radiology, Turku University Hospital, Turku, Finland); Daniel Strbian, MD, PhD, MSc (Stroke Med) (Department of Neurology, Helsinki University Hospital and University of Helsinki, Helsinki, Finland); France: Jean-Christophe Genric, MD (Brest University Hospital, Brest, France); Elsa Magro, MD (Brest University Hospital, Brest, France); Olivier Naggara, MD, PhD (Université de Paris, GHU Paris, INSERM 1266 CPN); Peggy Reiner, MD (Lariboisiere, France); Germany: Amr Abdulazim, MD (Department of Neurosurgery, Mannheim University Hospital, Mannheim, Germany); Ferdinand O Bohmann, MD (Department of Neurology, University Hospital/ Goethe University, Frankfurt, Germany); Stefan Boskamp, MD (Department of Neurology, Albertinen Krankenhaus, Hamburg, Germany); Johannes C Gerber, MD (Institute of Neuroradiology, University Hospital Carl Gustav Carus, Dresden, Germany); Dresden Neurovascular Center, University Hospital Carl Gustav Carus, Dresden, Germany); Daniel P O Kaiser, MD (Institute of Neuroradiology, University Hospital Carl Gustav Carus, Dresden, Germany); Else Kröner Fresenius Center for Digital Health, TU Dresden, Dresden, Germany; Dresden Neurovascular Center, University Hospital Carl Gustav Carus, Dresden, Germany); Roxane-Isabelle Kestner, MD (Department of Neurology, Goethe University Frankfurt, Frankfurt, Germany); Joshua Mbroh, MD, MSc (Department of Neurology Hertie Institute for Clinical Brain Research,

Eberhard-Karls University, Tuebingen, Germany); Milad Neyazi, MD (Department of Neurosurgery, Mannheim University Hospital, Mannheim, Germany); Michael Rosenkranz, MD (Department of Neurology, Albertinen Krankenhaus, Hamburg, Germany); Sven Poli, MD, MSc (Department of Neurology & Stroke, Eberhard-Karls University, Tuebingen, Germany); Hertie Institute for Clinical Brain Research, Eberhard-Karls University, Tuebingen, Germany); Götz Thomalla, MD (Universitätsklinikum Hamburg-Eppendorf, Klinik und Poliklinik für Neurologie, Hamburg, Germany); Greece: Theodoros Karapanayiotides, MD (2nd Department of Neurology, AHEPA University Hospital, Aristotle University of Thessaloniki, School of Medicine, Faculty of Health Sciences, Greece); Odysseas Kargiotis, MD (Stroke Unit, Metropolitan Hospital, Piraeus, Greece); Ioanna Koutroulou, MD (2nd Department of Neurology, AHEPA University Hospital, Aristotle University of Thessaloniki, School of Medicine, Faculty of Health Sciences, Greece); Lina Palaoidimou, MD (2nd Department of Neurology, 'Attikon' University Hospital, National and Kapodistrian University of Athens, Athens, Greece); Guatemala: José Domingo Barrientos Guerra, MD (Hospital General San Juan de Dios, Guatemala); India: Vikram Huded, MD (Mazumdar Shaw Medical Center, Bangalore, Karnataka, India); Shashank Nagendra, MD (Department of Neurology, Grant Medical College and Sir JJ Hospital, Mumbai, India); Chintan Prajapati, MD (Mazumdar Shaw Medical Center, Bangalore, Karnataka, India); Indonesia: Angga Krishna, MD (Department of Neurology, Faculty of Medicine Udayana University, Sanglah General Hospital Denpasar, Bali, Indonesia); Achmad Firdaus Sani, MD (Dr. Soetomo General Hospital Surabaya, Universitas Airlangga, Indonesia); Iran: Abdoreza Ghoreishi, MD (Stroke Research Group, Head of Stroke Care Unit, Department of Neurology, Vali-e-Asr Hospital, School of Medicine, Zanjan University of Medical Sciences, Iran); Reza Bahrami Ilkhchi, MD (Department of Neurosurgery, Shohada Hospital, Tabriz University of Medical Sciences, Tabriz, Iran); Javad Jalili, MD (Department of Radiology, Imam Reza Hospital, Faculty of Medicine, Tabriz University of Medical Sciences, Tabriz, Iran); Israel: Sergiu Ionut Sabetay, MD (Neurology Department, Hillel Yaffe Medical Center, Hadera, Israel); Tariq Abu Raya, MD (Neurology Department, Hillel Yaffe Medical Center, Hadera, Israel); Italy: Maurizio Acampa, MD, PhD (Stroke Unit, University of Siena, Siena, Italy); Marco Longoni, MD ('Maurizio Bufalini' Hospital, Cesena, Italy); Claudia Rolla Bigliani, MD (IRCCS San Martino Genova, Italy); Dipartimento di Neuroradiologia Diagnostica e Interventistica Policlinico Universitario IRCCS San Martino, Genova Italy); Lucio Castellan, MD (Policlinico Universitario IRCCS San Martino Genova, Italy); Dipartimento di Neuroradiologia Diagnostica e Interventistica Policlinico Universitario IRCCS San Martino, Genova Italy); Raffaele Ornello, MD, PhD (Neuroscience Section, Department of Biotechnological and Applied Clinical Sciences, University of L'Aquila, Italy); Leonardo Renieri, MD (Interventional Neurovascular Unit, Careggi University Hospital, Florence); Michele Romoli, MD (Neurology and Stroke Unit, Department of Neuroscience, Bufalini Hospital, Cesena, Italy); Simona Sacco, MD (Neuroscience Section, Department of Biotechnological and Applied Clinical Sciences, University of L'Aquila, Italy); Davide Sangalli, MD (Neurological Department, 'Alessandro Manzoni' Hospital, ASST Lecco, Via dell'Eremo 9/11, 23900, Lecco, Italy); Martina Viganò, MD (Neurological Department, 'Alessandro Manzoni' Hospital, ASST Lecco, Via dell'Eremo 9/11, 23900, Lecco, Italy); University of Milano-Bicocca, Milan, Italy); Andrea Zini, MD (IRCCS Istituto delle Scienze Neurologiche di Bologna, Neurology and Metropolitan Stroke Center, Maggiore Hospital, Bologna, Italy); Japan: Hiroshi Tokimura, MD (Department of Neurosurgery and Stroke Center, Kagoshima City Hospital, Kagoshima, Japan); Kazutaka Sonoda, MD (Department of Neurology, Saiseikai Fukuoka General Hospital, SFGH, Japan); Kenichi Todo, MD (Stroke Center, Osaka University Hospital, Japan); Hiroki Fukuda, MD (Department of Neurology, Japanese Red Cross Matsue Hospital, Japan); Kyohai Fujita, MD (Department of Endovascular Surgery, Tokyo Medical and Dental University, Tokyo, Japan); Manabu Sakaguchi, MD (Department of Neurology, Osaka General Medical Center, Japan); Masaaki Uno, MD (Department of Neurosurgery, Kawasaki Medical School, Japan); Issei Kan, MD (Department of Neurosurgery, The Jikei University School of Medicine); Miyake Kosuke, MD (Shiroyama Hospital, Japan); Ryuhei Kono, MD (Department of Neurology, Kin-ikyō Chuo Hospital, Japan); Naoto Kimura, MD (Department of Neurosurgery, Iwate Prefectural Central Hospital, Japan); Nobuaki Yamamoto, MD (Advanced Brain Research, Tokushima University, Japan); Ryoo Yamamoto, MD (Yokohama Brain and Spine Center, Japan); Ryosuke Doijiri, MD (Department of Neurology, Iwate Prefectural Central Hospital, Japan); Seigo Shindo, MD (Department of Neurology, Japanese Red Cross Kumamoto Hospital, Japan); Nobuyuki Ohara, MD (Department of Neurology, Kobe City Medical Center General Hospital); Hiroto Imamura, MD (Department of Neurosurgery, Kobe City Medical Center General Hospital); Takehiro Ogawa, MD (Department of Neurosurgery, Japanese Red Cross Kyoto Daini Hospital, Japan); Takeshi Uwatoko, MD (Cerebrovascular Medicine, Stroke Center, Saga Medical Centre Koseikan, Japan); Takuya Kanamaru, MD (NTT Medical Center Tokyo, Tokyo, Japan); Toshiyuki Fujinaka, MD, PhD (Department of Neurosurgery, National Hospital Organization Osaka National Hospital, Japan); Yohei Takenobu, MD (Osaka Red Cross Hospital, Japan); Kazunori Toyoda, MD (Department of Cerebrovascular Medicine, National Cerebral and Cardiovascular Center, Japan); Yuji Matsumaru, MD (Department of Stroke and Cerebrovascular Diseases, University of Tsukuba Hospital, Japan); Yukako Yazawa, MD (Department of Stroke Neurology, Kohnan Hospital, Sendai, Japan);

Yuri Sugiura, MD (Toyonaka Municipal Hospital, Japan); Korea: South: Jang-Hyun Baek, MD (Department of Neurology, Kangbuk Samsung Hospital, Sungkyunkwan University School of Medicine, Seoul, South Korea, Republic of Korea); Young Sub Kwon, MD (Department of Neurosurgery, National Health Insurance Service Ilsan Hospital, Goyang, Korea); Yun Ho Lee, MD (Department of Neurosurgery, National Health Insurance Service Ilsan Hospital, Goyang, Korea); Kwon-Duk Seo, MD (Department of Neurology, National Health Insurance Service Ilsan Hospital, Goyang, Korea); Sung-Il Sohn, MD (Department of Neurology, Keimyung University Dongsan Hospital, Keimyung University School of Medicine, Daegu, South Korea); Malaysia: Yong Chieh Chan, MD (Hospital Sultan Abdul Halim, Malaysia); Wan Asyraf Wan Zaidi, Mmed (National University of Malaysia, Malaysia); Mexico: Javier Barrientos-Prieto, MD (Neurology Department, University Hospital Jose Eleuterio Gonzalez, Universidad Autonoma de Nuevo Leon); Fernando Gongora-Rivera, MD, PhD (Neurovascular Unit and Neurology Department, University Hospital Jose Eleuterio Gonzalez, Universidad Autonoma de Nuevo Leon and Zambrano Hellion Medical Center, Tec Salud, Mexico); Manuel Martinez-Marino, MD, MSc (Department of Neurology, Hospital de especialidades del Centro Médico Nacional Siglo XXI IMSS, Mexico); Alejandra Calderón-Vallejo, MD, MSc (Department of Neurology, Hospital de especialidades del Centro Médico Nacional Siglo XXI IMSS, Mexico); Moldova: Stanislav Groppa, MD, PhD ('Nicolae Testemitanu' State University of Medicine and Pharmacy; Emergency Medicine Institute, Chisinau, Republic of Moldova); Leahu Pavel, MD, PhD student ('Nicolae Testemitanu' State University of Medicine and Pharmacy; Emergency Medicine Institute, Chisinau, Republic of Moldova); Netherlands: Jonathan M Coutinho, MD PhD (Amsterdam University Medical Centers, Amsterdam, the Netherlands); Diederik Dippel, MD PhD (Erasmus MC, University Medical Center Rotterdam, Department of Neurology, Netherlands); Leon Rinkel, MD (Amsterdam University Medical Centers Amsterdam, Netherlands); Dianne H K van Dam-Nolen, MD (Erasmus MC, University Medical Center Rotterdam, (1) Department of Neurology, (2) Department of Radiology and Nuclear Medicine, Rotterdam, Netherlands); Nigeria: Ernest Okwundu Nwazor, MBBS, FMCP (Department of Medicine, Federal Medical Center Owerri, Neurology Unit, Federal Medical Centre, Owerri, Nigeria Imo, Nigeria); Taofiki Ajao Sunmonu, MD (Federal Medical Centre, Owo, Ondo, Nigeria); Norway: Espen Saxhaug Kristoffersen, MD, PhD (Department of Neurology, Akershus University Hospital, University of Oslo, Oslo, Norway); Oman: Amal M Al Hashmi, MD (Central Stroke Unit, Neuroscience Directorate, Khoula Hospital, Ministry of Health, Oman); Pakistan: Saima Ahmad, MBBS (Lahore General Hospital, Lahore, Pakistan); Umair Rashid, MBBS (Lahore General Hospital, Lahore, Pakistan); Peru: Liliana Rodriguez-Kadota, MD (Departamento de Neurología, Hospital Nacional Edgardo Rebagliati Martins, Essalud, Lima, Perú); Miguel Ángel Vences, MD (Departamento de Neurología, Hospital Nacional Edgardo Rebagliati Martins, Essalud, Lima, Perú); Philippines: Patrick Matic Yaldo, MD (Stroke Service, St. Luke's Medical Center, Global City, Philippines); Jon Stewart Hao Dy, MD (Stroke Service, St. Luke's Medical Center, Quezon City, Philippines); Poland: Waldemar Brola, MD, PhD (Department of Neurology, Specialist Hospital Konskie, Collegium Medicum, Jan Kochanowski University, Kielce, Poland); Aleksander Dębiec, MD (Clinic of Neurology, Military Institute of Medicine, Szaserow 128, 04-141 Warsaw, Poland); Malgorzata Dorobek, MD, PhD (Department of Neurology, Central Clinical Hospital of the Ministry of Internal and Administration, Warsaw, Poland); Michal Adam Karlinski, MD, PhD (2nd Department of Neurology, Institute of Psychiatry and Neurology, Warsaw, Poland); Beata M Labuz-Roszak, MD, PhD (Department of Neurology, St. Jadwiga Provincial Specialist Hospital, Institute of Medical Sciences, University of Opole, Opole, Poland); Anetta Lasek-Bal, MD, PhD (Department of Neurology, Leszek Giec Upper Silesian Medical Centre of the Silesian Medical University in Katowice, School of Health Sciences, Medical University of Silesia in Katowice, Katowice, Poland); Halina Sienkiewicz-Jarosz, MD, PhD (1st Department of Neurology, Institute of Psychiatry and Neurology, Warsaw, Poland); Jacek Staszewski, MD, PhD (Clinic of Neurology, Military Institute of Medicine, Szaserow 128, 04-141 Warsaw, Poland); Piotr Sobolewski, MD (Department of Neurology in Sandomierz, Collegium Medicum, Jan Kochanowski University in Kielce, Sandomierz, Poland); Marcin Wiącek, MD (Department of Neurology, Institute of Medical Sciences, Medical College of Rzeszow University, 1A Warzywna Street, 35-310 Rzeszow, Poland); Justyna Zielinska-Turek, MD (Department of Neurology, Central Clinical Hospital of the Ministry of Internal and Administration, Warsaw, Poland); Portugal: André Pinho Araújo, MD (Neuroradiology Department - Centro Hospitalar de Vila Nova de Gaia/Espinho, Portugal); Luísa Fonseca, MD (Stroke Unit, Medicine Department, Centro Hospitalar Universitário de São João, Portugal); M Luís Silva, MD (Centro Hospitalar Universitário de São João, Portugal); Pedro Castro, MD PhD (Department of Neurology, Centro Hospitalar Universitário de São João, Portugal); Mariana Rocha, MD (Neurology Department, Centro Hospitalar Vila Nova de Gaia/Espinho); Romania Cristian Falup-Pecurariu, MD, PhD (Transilvania University, Faculty of Medicine, Brasov, Romania); Singapore: Narayanaswamy Venketasubramanian, MD (Raffles Neuroscience Centre, Raffles Hospital, Singapore); Slovakia: Georgi Krastev, MD, PhD, Miroslav Mako, MD (Department of Neurology, Faculty Hospital Trnava, Jessenius Medical Faculty Martin, Comenius University, Bratislava); Spain: Oscar Ayo-Martin MD, PhD (Complejo Hospitalario Universitario de Albacete, Albacete, Spain); Jordi Blasco, MD, PhD (Interventional Neuroradiology, Hospital Clinic de Barcelona, Spain); Antonio Cruz-Culebras, MD (Department of Neurology (Unidad

de Ictus), Hospital Universitario Ramón y Cajal, Madrid, Spain); Francisco Hernandez-Fernandez, MD, PhD (Complejo Hospitalario Universitario de Albacete, Albacete, Spain); Claudio Rodríguez Fernández, MD (Department of Neuroradiology, Hospital Universitario Rey Juan Carlos, Spain); Jorge Escartín López, MD (Department of Neuroradiology, Hospital Universitario Rey Juan Carlos); Alejandro Rodríguez, MD (Comprehensive Stroke Center, Hospital Clínic de Barcelona, Spain); Switzerland: Manuel Bolognese, MD (Neurocenter, Cantonal Hospital of Lucerne, Lucerne, Switzerland); Grzegorz Marek Karwacki, MD (Department of Radiology and Nuclear Medicine, Luzerner Kantonsspital, Lucerne, Switzerland); Emanuela Keller, MD (University Hospital, University of Zurich, Switzerland); Paolo Machi, MD (Interventional Neuroradiology, University Hospitals of Geneva, Switzerland); Gianmarco Bernava, MD (Interventional Neuroradiology, University Hospitals of Geneva, Switzerland); Thailand: Surawan Boonyakarnkul, MD (Ramathibodi hospital, Mahidol University, Thailand); Anchalee Churojana, MD (Department of Radiology, Siriraj Hospital, Mahidol University, Thailand); Tunisia: Nadia Hammami, MD (Department of Neuroradiology, Tunis El Manar University, National Institute of Neurology Tunis, Tunisia); Turkey: Arside Bajrami, MD (Istanbul Aydin University, Florya Medicalpark Stroke Center, Turkey); Songul Senadim, MD (Istanbul Aydin University, Florya Medicalpark Stroke Center, Turkey); UAE: Syed I Hussain, MD (Cleveland Clinic Abu Dhabi, UAE); Seby John, MD (Cleveland Clinic Abu Dhabi, UAE); UK: Graham Dow, MD (Nottingham University Hospitals NHS Trust); Kailash Krishnan, MD, PhD (Nottingham University Hospitals NHS Trust); Robert Lenthall, MB, BS (Nottingham University Hospitals NHS Trust); Ken Wong, MD (Royal London Hospital, Barts Health NHS Trust, London, UK); Liqun Zhang, MD, PhD (St George's University Hospital, London, UK); USA: Dorothea Altschul, MD (Valley Hospital Health System, Neurosurgeons of NJ, New Jersey, USA); Kaiz S Asif, MD (Amrita Health and University of Illinois-Chicago, Chicago, USA); Mohammad A Aziz-Sultan, MD (Brigham and Women's Hospital); Ivo Bach, MD (Rutgers University) Zeelalem Bahiru, NP (Inova Fairfax Hospital, Virginia, USA); Kristine Below, BS (Neuroscience and Stroke Program, Bon Secours Mercy Health St Vincent Hospital, Toledo, Ohio); Jose Biller, MD (Loyola University Chicago Stritch School of Medicine, Illinois, USA); Anna M. Cervantes-Arslanian, MD (Boston Medical Center); Saqib A. Chaudhry, MD (Inova Fairfax Hospital, University of Virginia School of Medicine, Virginia, USA); Alex Chebl, MD (Henry Ford Health System, Detroit, Michigan, USA); Michael Chen, MD (Rush University, Illinois, USA); Marco Colasurdo, MD (Department of Radiology, University of Texas Medical Branch, Galveston, Texas, USA); Alexandra Czap, MD (Neurology, McGovern Medical School at the University of Texas Health Science Center, Houston, Texas, USA); Hormuzdiyar Dasenbrock, MD MPH (Boston Medical Center); Adam H. de Havenon, MD (University of Utah, Utah, USA); Sushrut Dharmadhikari MD (Baptist Health Medical Center - Little Rock, Little Rock, Arkansas, USA); Adam A. Dmytriw, MD MPH MSc (Brigham & Women's Hospital, Boston, USA); Clifford J. Eskey, MD, PhD (Dartmouth Hitchcock Medical Center, Lebanon, New Hampshire, USA); Mark Etherton, MD, PhD (Department of Neurology, Massachusetts General Hospital, Boston, Massachusetts, USA); Chizoba Ezepe, MD (Department of Interventional and Vascular Neurology, Neuroscience Center, SSM Health DePaul Hospital, St. Louis, Missouri, USA); Lauren Fink, BSN, RN (Santa Barbara Cottage Hospital); Ulviyya Gasimova, MD (Department of Neurology, Saint Louis University School of Medicine, Missouri, USA); Nitin Goyal, MD (University of Tennessee Health Science Center, Tennessee, USA); Kasey B Grimmitt, RN, BSN (Baptist Health Medical Center - Little Rock, Little Rock, Arkansas, USA); Maryam Hakemi, MSN, NP (Wayne State University, Detroit, MI, Detroit, Michigan, USA); Taryn Hester, BSN, RN, (Cooper Neurological Institute, Cooper University Hospital, Camden, NJ, USA); Violiza Inoa, MD (University of Tennessee Health Science Center, Tennessee, USA); Peter T. Kan, MD, MPH (Department of Neurosurgery, University of Texas Medical Branch, USA); Ekkehard M. Kasper, MD DPhil (St. Elizabeth's Medical Center, USA); Priyank Khandelwal, MD, (Rutgers University, USA); Rakesh Khatri, MD (Department of Neurology, Texas Tech University Health Science Center, El Paso, Texas), Ayaz M Khawaja, MD (Wayne State University, Detroit, MI, Detroit, Michigan, USA); Naim N. Khoury, MD (HSHS St. John's Hospital, Southern Illinois University School of Medicine, Springfield, USA); Benny S. Kim, MD (Virginia Hospital Center, Virginia, USA); Murali Kolikonda, MD (Baptist Health Medical Group, Baptist Health Lexington, Lexington, Kentucky, USA); Anna Luisa Kuhn, MD, PhD (Division of Neurointerventional Radiology, Department of Radiology, University of Massachusetts Medical Center, Worcester, Massachusetts, USA); Guillermo Linares, MD (Vascular and Neurointerventional Services, Saint Louis University, Missouri, USA); Italo Linfante, MD (Miami Cardiac & Vascular Institute, Miami Neuroscience Institute, Miami, FL, USA); Aaron I. Loochtan, DO (Ohio Health Riverside Methodist Hospital, Ohio, USA); Timothy G. Lukovits, MD (Dartmouth Hitchcock Medical Center, Lebanon, New Hampshire, USA); Shailesh S. Male, MD (Department of Neurology & Neurosurgery, Vidant Medical Center, Greenville, North Carolina, USA); Laith Maali, MD (Department of Neurology, University of Kansas Medical Center, USA); Hesham E Masoud, MD (Department of Neurology, SUNY Upstate, Syracuse, New York, USA); Elsi Milagros Galecio-Castillo (University of Iowa, Iowa, USA); Jianguyong Min, MD, PhD (Department of Neurosciences and Comprehensive Stroke Center, Spectrum Health and Michigan State University College of Human Medicine, Michigan, USA); Ghada A. Mohamed, MD (Emory University School of Medicine, Georgia, USA); Krishna Nalleballe, MD (Department of Neurology, University of Arkansas for Medical Sciences (UAMS),

Arkansas, USA); Santiago Ortega-Gutierrez, MD, MSc, (University of Iowa, Iowa, USA) Ajit S Puri, MD (Division of Neurointerventional Radiology, Department of Radiology, University of Massachusetts Medical Center, U Mass, Worcester, Massachusetts, USA); Yazan Radaideh, MD (Rush University, Illinois, USA), Rahul H. Rahangdale, MD (Ascension St Johns Medical Center, Tulsa, Oklahoma, USA); Pankajavalli Ramakrishnan, MD PhD (Riverside Regional Medical Center, Newport News Virginia); Aravind B. Reddy, MD (SUNY Upstate, Syracuse, New York, USA); Sean Ruland, DO (Loyola University Chicago Stritch School of Medicine, Illinois, USA); Setareh Salehi Omran, MD (University of Colorado School of Medicine, Aurora, CO); Sunil A. Sheth, MD (Neurology, UHealth McGovern Medical School, Houston, TX, USA, Houston, Texas, USA); James E. Siegler, MD (Cooper Neurological Institute, Cooper University Hospital, Camden, NJ, USA); Amy K. Starosciak, PhD (Miami Neuroscience Institute, Miami, USA); Nicholas E Tarlov, MD (Community Memorial Hospital, Ventura, California, USA); Robert A. Taylor, MD (Santa Barbara Cottage Hospital); Jenny Tsai, MD (Neurological Surgery, Department of Neurosciences and Comprehensive Stroke Center, Spectrum Health and Michigan State University College of Human Medicine, Michigan, USA); Michael J. Wang, MD (UNC School of Medicine, North Carolina, USA); Ka-Ho Wong, BS, MBA (University of Utah, USA); Osama O. Zaidat, MD, MS (Neuroscience and Stroke Program, Bon Secours Mercy Health St Vincent Hospital, Toledo, Ohio); Vietnam Huynh Vu Le, MD (Hue Central, Hue, Vietnam) Thong Nhu Pham, MD (Da Nang Hospital, Da Nang, Vietnam); Hoang Thi Phan, MD (Bach Mai Hospital, Hanoi, Vietnam and University of Tasmania, Tasmania, Australia); Mai Duy Ton, MD (Bach Mai Hospital, Hanoi, Vietnam); Anh Duc Tran, MD (Hue Central, Hue, Vietnam); Senior authors: Kristina Sirakova, MD (Radiology, UH Alexandrovska, Sofia, Bulgaria); Markus A. Möhlenbruch, MD (Interventional Neuroradiology, Heidelberg University Hospital, Heidelberg, Germany); Simon Nagel, MD (Neurology, Heidelberg University Hospital, Heidelberg, Germany); Ludwigshafen City Hospital, Ludwigshafen, Germany); Jean Raymond, MD (Centre Hospitalier de l'Université de Montreal, Canada); Raul G. Nogueira, MD (Neurology and Neurosurgery, University of Pittsburgh Medical Center, Pittsburgh, USA).

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